

What is claimed is:

1. A high aspect ratio microelectromechanical system device for measuring an applied force, the device comprising:
  - a frame;
  - 5 a proof mass coupled to the frame for in-plane motion along an axis of symmetry, the proof mass having first and second pluralities of spaced apart capacitor plates projected therefrom on each side of the axis of symmetry and oriented substantially crosswise to the axis of symmetry; and
    - third and fourth pluralities of spaced apart capacitor plates oriented substantially crosswise to the axis of symmetry of the proof mass and intermeshed respectively with the first and second pluralities of capacitor plates, the third and fourth pluralities of capacitor plates being suspended for motion relative to the frame about respective first and second axes of rotation oriented substantially parallel with the axis of symmetry of the proof mass.
2. The device of claim 1, further comprising first and second torsional flexures respectively coupled between the third and fourth pluralities of capacitor plates and the frame.
3. The device of claim 2 wherein each of the first and second torsional flexures further comprises a pair of torsional flexures spaced at opposite ends of the respective third and fourth pluralities of capacitor plates.
- 20 4. The device of claim 3, further comprising an attachment structure coupled between each of the first and second torsional flexures and the frame.
5. The device of claim 4 wherein a first end of each of the first and second torsional flexures is fixed relative to the attachment structure and a second end is fixed relative to the respective third and fourth pluralities of capacitor plates.
- 25 6. The device of claim 3 wherein each of the torsional flexures further comprises a beam-shaped flexure having a length dimension measured along the respective axis of

rotation that is greater than a width dimension measured crosswise to the axis of symmetry of the proof mass.

7. A high aspect ratio microelectromechanical system device for measuring an applied force, the device comprising:

5 a proof mass having first and second pluralities of electrodes extending on opposing first and second sides of an axis of symmetry and having spaces formed between adjacent electrodes;

first and second sets of reference electrodes being spaced from the proof mass on the opposing first and second sides of the axis of symmetry, each set of reference electrodes

10 further comprising a plurality of electrodes positioned in the spaces between the proof mass electrodes;

a frame;

one or more proof mass flexures suspending the proof mass relative to the frame for displacement along the axis of symmetry; and

15 first and second reference electrode flexures suspending the respective first and second sets of reference electrodes relative to the frame for motion about respective first and second axes substantially parallel with the proof mass axis of symmetry.

8. The device of claim 7, further comprising a substrate whereof the proof mass and first and second sets of reference electrodes are formed.

20 9. The device of claim 8 wherein the proof mass and first and second sets of reference electrodes are formed having substantially the same uniform thickness.

10. The device of claim 7 wherein the first and second reference electrode flexures further comprise first and second pluralities of electrodes.

11. The device of claim 10 wherein one end of the each of the first and second reference 25 electrode flexures is mechanically coupled in fixed relation to the frame.

12. The device of claim 11 wherein each of the first and second reference electrode flexures is long as measured in the respective first and second axes relative to a respective width measured crosswise to the respective first and second axes.
13. An in-plane comb-type capacitive readout force transducer fabricated as a high aspect ratio microelectromechanical system device for measuring an applied force, the transducer comprising:
  - an instrument frame;
  - a substrate of substantially uniform thickness having substantially planar and mutually parallel spaced apart upper and lower surfaces;
  - 10 a proof mass formed in the substrate of substantially uniform width and length and suspended by one or more flexures at each of two opposing ends for motion relative to the frame in the plane of the substrate and along an axis of motion crosswise to the width, the proof mass having on each of two edges spaced apart by the width a plurality of outwardly projected electrode fingers spaced along the length and aligned substantially crosswise to the
  - 15 axis of motion and forming individual substantially planar capacitor plates oriented substantially crosswise to the axis of motion; and
    - first and second pluralities of frame electrode fingers formed in the substrate and spaced on opposite sides of the proof mass and substantially fixedly secured to the frame relative to the axis of motion of the proof mass, the first and second pluralities of frame
    - 20 electrode fingers being inwardly projected toward the proof mass and inter-spaced with the outwardly projected fingers spaced along the length of the proof mass and forming individual substantially planar capacitor plates oriented substantially crosswise to the axis of motion of the proof mass and cooperating with the capacitor plates of the proof mass for forming individual capacitors therebetween when an electrical current is applied thereto, each of the
    - 25 first and second pluralities of frame electrode fingers being suspended by one or more torsional flexures for motion relative to the frame about respective first and second axes of rotation aligned substantially parallel with the axis of motion of the proof mass.
14. The transducer of claim 13 wherein each of the torsional flexures is coupled to an attachment structure that is fixedly secured to the frame.

15. The transducer of claim 13 wherein each of the torsional flexures is structured having a length measured along the respective axis of rotation that is greater than a width measured crosswise to the axis of motion of the proof mass.
16. The transducer of claim 13 wherein each of the first and second pluralities of frame electrode fingers further comprises a plurality of sets of frame electrode fingers, each of the sets of frame electrode fingers being suspended by pairs of torsional flexures for rotation relative to the frame about one of the respective first and second axes of rotation.
17. The transducer of claim 13, further comprising first and second spines each structured as a substantially rigid support structure interconnecting the respective first and second pluralities of frame electrode fingers.
18. The transducer of claim 17, further comprising substantially rigid attachment structure fixedly secured to the frame, the torsional flexures being interconnected between each of the spines and the attachment structure.
19. A method of forming a suspension structure for compensating out-of-plane displacements of a proof mass of a device formed as a high aspect ratio microelectromechanical system, the method comprising:
  - forming a frame in a first substrate;
  - using a high aspect ratio microelectromechanical system method of fabrication, forming in a second substrate:
  - 20 a proof mass having first and second sets of spaced apart capacitor plates projected therefrom on each side of an axis of symmetry and oriented substantially crosswise to the axis of symmetry,
  - one or more flexures coupled to the proof mass along the axis of symmetry, third and fourth sets of spaced apart capacitor plates oriented substantially crosswise to the axis of symmetry of the proof mass and intermeshed respectively with the first and second sets of capacitor plates, and

first and second torsional flexures coupled to the third and fourth sets of capacitor plates along respective first and second axes of motion substantially aligned with the axis of symmetry of the proof mass;

- securing the in-line flexures for suspending the proof mass for primary motion along 5 the axis of symmetry; and
- securing ends of the torsional flexures for suspending the third and fourth sets of capacitor plates for motion about the respective first and second axes of motion.

20. The method of claim 19 wherein each of the first and second torsional flexures further comprises a pair of torsional flexures coupled at opposite ends of the third and fourth sets of 10 capacitor plates, and securing ends of the torsional flexures further comprises securing ends of the torsional flexures distal from the capacitor plates.

21. The method of claim 20 wherein securing ends of the torsional flexures further comprises securing an attachment structure formed at the ends of the torsional flexures distal from the capacitor plates.

15 22. The method of claim 19 wherein forming first and second torsional flexures further comprises forming first and second pairs of torsional flexures having a length along the respective first and second axes of motion relative to a width crosswise to the respective first and second axes of motion that causes the respective third and fourth sets of capacitor plates to rotate relative to the frame in response to a force applied perpendicular to a plane 20 containing the proof mass.